Profitable lessons from non-profits

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Operations research is the application of analytical methods and tools to understand and improve systems. In the middle of the 20th century, operations research played a critical role in building the US military. Later in the 20th century, operations research helped to redefine efficient supply chain management for the country’s largest companies. With the past century of research, we now understand how to design and manage efficient systems in settings where the goal is to minimize cost or maximize profit. We know considerably less about operations in non-profit settings in which goals such as equitable distribution of resources and societal welfare are more difficult to model.

After the 2004 Asian tsunami, the United Nations Emergency Aid coordinator stated, “We see now as our biggest challenge not the availability of funds nor the availability of supplies that are in the pipeline, but the logistical constraints on getting it out to people.” One might conjecture that models developed for commercial logistics systems could address the logistical challenges in relief efforts. Yet, this is not often the case. Many models are not well-suited for non-profit operations. The differences in objectives of commercial and non-profit operations as well as in the nature of their respective demands and resources call for new mathematical models and solution approaches.

Consider a simple problem of delivering goods from supply node A to demand nodes B, C, and D using one truck, shown in Figure 1. In most commercial settings, the goal is to deliver goods with minimum travel cost and/or time. Here, one finds the tour from A to B, C, and D, returning to A, with minimum travel time. This problem is known as the traveling salesman problem. The optimal solution (Figure 1.left) delivers goods in the sequence of B to D to C.

Afterwards, one might conjecture that models developed for commercial logistics systems could address the logistical challenges in relief efforts. Yet, this is not often the case. Many models are not well-suited for non-profit operations. The differences in objectives of commercial and non-profit operations as well as in the nature of their respective demands and resources call for new mathematical models and solution approaches.

Consider the same example in a relief setting following a disaster. Time-critical supplies must be delivered from node A to B, C, and D. The route in Figure 1.left visits the last node at 6 pm. If one minimizes the latest arrival time to any node, sequencing visits as B, C, and then D (Figure 1.right) reduces the latest arrival time to 2 pm. This time savings can be vitally important in applications such as medical supply distribution in a pandemic outbreak, as shown in Campbell et al. (1).

The complexities of disaster relief go beyond this example; many complexities are identified in recent studies (2,3). Relief agencies work in environments of great uncertainty in demand, resources, and processes. The low-probability, high-impact nature of disasters complicates the modeling of uncertainty. Vehicle routing models exist for commercial applications with uncertain demand or supply (seldom both simultaneously); however, it is easier to develop contingency plans when the range of expected outcomes is somewhat bounded by historical performance. This is more difficult in disaster settings where the timing, location and magnitude of events cannot be adequately predicted. The impact of a disaster may not be known initially. The disaster can also compromise, or destroy, the transportation networks needed to deliver aid. A Fritz Institute

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study of relief agencies involved in the Asian Tsunami (4) revealed that much of the local transportation network in Indonesia and Sri Lanka was destroyed by the Tsunami. Disaster relief requires a level of agility and adaptability beyond what presently exists in commercial settings. Van Wassenhove (3) notes that these insights can be valuable in commercial logistics where extreme supply or demand events, while uncommon, can cause enormous financial consequences.

To further address the uncertainty in disaster occurrence, research has emerged in supply pre-positioning in anticipation of disasters (5,6). In commercial settings, risk pooling strategies suggest a centralization of safety stock to allow companies to hedge against demand spikes or supply shortages. In disaster relief, centralizing supplies can cause unacceptably long lead times in delivering aid. Distributing supplies globally is essential: pre-positioning can accelerate disaster response, making use of warehouse facilities such as those provided by the United Nations. Duran et al. (5) developed a global warehouse plan for CARE International, reducing their average response time from weeks to days, depending on the number and capacity of warehouses.

Pre-positioning, on the other hand, requires coordination which can be difficult in relief settings which are typically characterized by decentralized decision making. The United Nations created the Joint Logistics Centre to centralize relief efforts in large-scale disasters. The centre played a key role in pre-positioning food supplies in anticipation of the extreme winter conditions in Afghanistan (3).

Differences between non-profit and commercial operations arise in areas beyond disaster relief. Many non-profit agencies lack powerful computational software or computers. Logistics planning often focuses on simplicity rather than on exploitation of technology. Bartholdi et al. (7) developed a vehicle routing plan for Meals-on-Wheels to distribute lunches to the elderly, based on the concept of space-filling curves, which could dynamically change routes, using a map of Atlanta and Rolodex files, in place of computers. Route travel times from this simple solution method were generally within 25% of the shortest possible routes.

Non-profit applications can lead to insightful variations of existing operations research problems. Working with a library delivery service, Francis et al. (8) discovered a new fundamental vehicle routing problem. Library delivery has greater flexibility in route scheduling than exists in commercial operations where visit frequency is set by a customer’s willingness-to-pay. Their model exploited this flexibility; raising visit frequency to some libraries actually lowered total travel time for the system. This work produced metrics to quantify operational complexity which are useful in commercial settings. For example, one can quantify the crewsize of a routing solution; i.e., the number of different drivers visiting a location over a period. Lower crewsize is critical in library delivery since some libraries require a key to access. Likewise, UPS sees a competitive advantage in lower crewsize in its package delivery operations to improve driver-customer relationships; sales leads from drivers account for 60 million packages annually (9).

We are beginning to uncover the potential of operations research techniques for a range of non-profit agencies, both in the advancement of operations research methodologies and in the resulting impact on society. In academic communities, there is a growing appreciation of the technical complexity of the problems. The National Academy of Engineering sponsored a recent workshop on Engineering, Ethics and Sustainable Communities and the Rockefeller Foundation recently sponsored a conference on Humanitarian Logistics in Africa. These conferences, as well as studies (2,3), have served as a call to action within the academic and non-profit communities to improve the visibility and sophistication of logistics within non-profit settings. The keys are education, multi-disciplinary research, and agile and adaptable solutions. Our challenge is to continually engage the operations research community in non-profit applications, highlighting the potential for new academic discoveries and the significant impact on society. Straightforward
application is not enough. Academics must focus on the unique characteristics of these applications, and not simply apply an old hammer to a new nail.

**References and notes**


(2) A. Thomas, L. Kopcazk, Fritz Institute (2005).


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